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Survival and Growth of Stocked Muskellunge: Effects of Genetic and Environmental Factors

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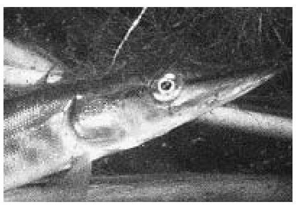

Abstract

Muskellunge fingerlings from 5 populations were stocked in paired groups to evaluate differences in survival and growth in six Wisconsin lakes. Short-term survival (<60 d) was higher for fingerlings from Mud/Callahan Lake, but all survival rates were within the range previously reported for Wisconsin lakes. Survival to maturity was difficult to assess because of low numbers of fish captured from most stockings. In Mud/Callahan Lake, where sufficient numbers of fish were captured, Mud/Callahan (M/C) muskellunge survival was better than Lac Courte Oreilles (LCO) muskellunge. Growth of both M/C and LCO muskellunge was slow in Mud/Callahan Lake. In other study lakes, growth of both LCO and M/C muskellunge was improved but the M/C muskellunge mean size was still less than LCO muskellunge. Results from this study suggest the poor size structure of adult muskellunge (most fish < 30 inches) observed in Mud/Callahan is likely the result of a combination of environmental and genetic factors.

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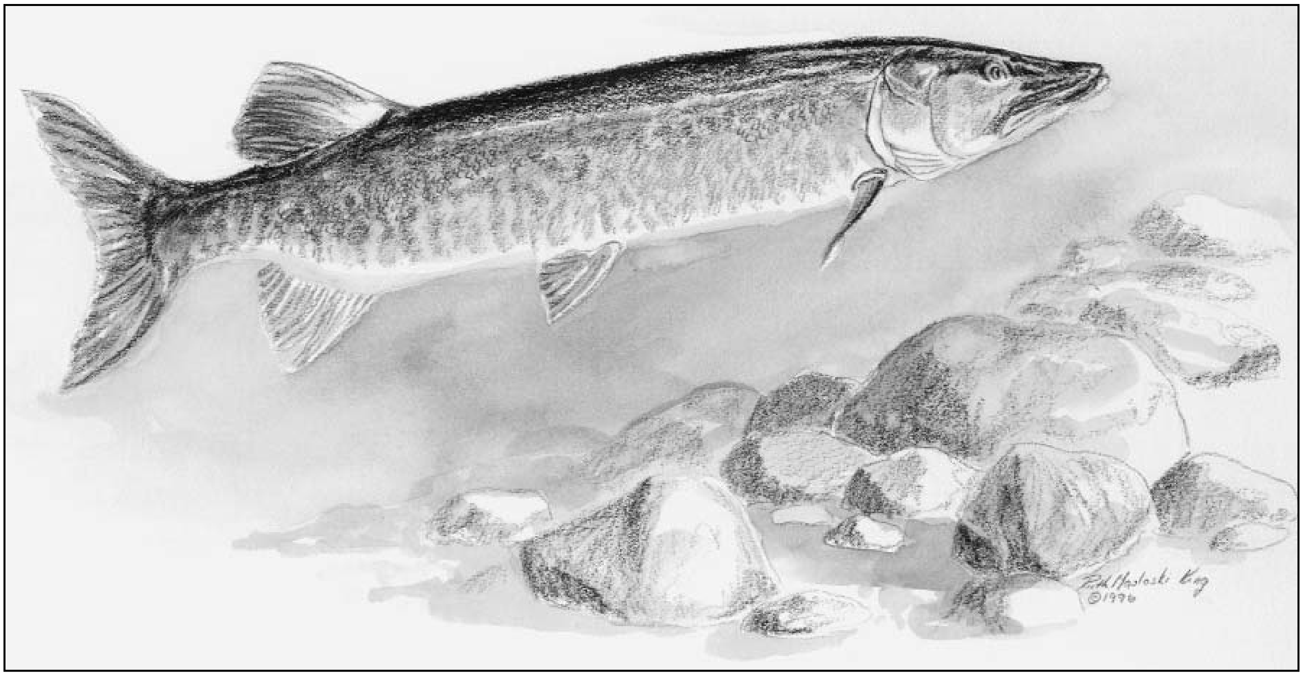

Introduction

Muskellunge (*Esox masquinongy*) management often involves stocking of cultured fish to supplement limited natural reproduction or to create new populations. In selecting wild populations for egg collection for propagation, hatcheries have historically considered traits conducive to hatchery performance, i.e. progeny growth and survival, and more recently, survival and contribution to the fishery after release (Piper et al. 1982). However, the release of cultured fish into waters to supplement existing populations has become an issue of concern. Mixing of cultured muskellunge via stocking with a natural population can cause loss of genetic fitness. If traits such as growth rates are genetically influenced these may be inadvertently passed to other waters. Genetic research has stressed the need to manage distinctive stocks of muskellunge, i.e. genetic conservation, to avoid introduction of maladaptive alleles (Koppelman and Philipp 1986).

Koppelman and Philipp (1986) found genetic differences among muskellunge populations across their natural range with electrophoretic techniques. Similarly, Hanson et al. (1983) found differences among Wisconsin and Minnesota populations. The lakes sampled by Hanson et al. (1983) included waters historically used as broodstock sources for propagation along with several waters characterized by slow growth, and poor size structure of adult muskellunge (most fish < 30 inches). One Minnesota population (Shoepac), characterized by slow growth but the primary broodstock source for propagation, was found to be different from the Leech Lake population (Hanson et al. 1983). Further field evaluation of these populations by Younk and Strand (1992) suggested growth was affected by genetic factors. These findings resulted in changing the wild stock of muskellunge where Minnesota collected eggs for propagation.

The study by Hanson et al. (1983) found differences between the Lac Courte Oreilles population, Wisconsin's primary brood lake, and Mud/Callahan Lake where fish were slow growing with a poor size structure. However, while this genetic study suggested differences did occur, the authors were unsure how they differed and what traits might be affected.

The objective of this study was to evaluate field performance, i.e. survival and growth, of several populations of muskellunge from Wisconsin and one population from Minnesota. We hoped that this study would provide more information on the relative importance of inherited traits and environmental influences on growth and survival.

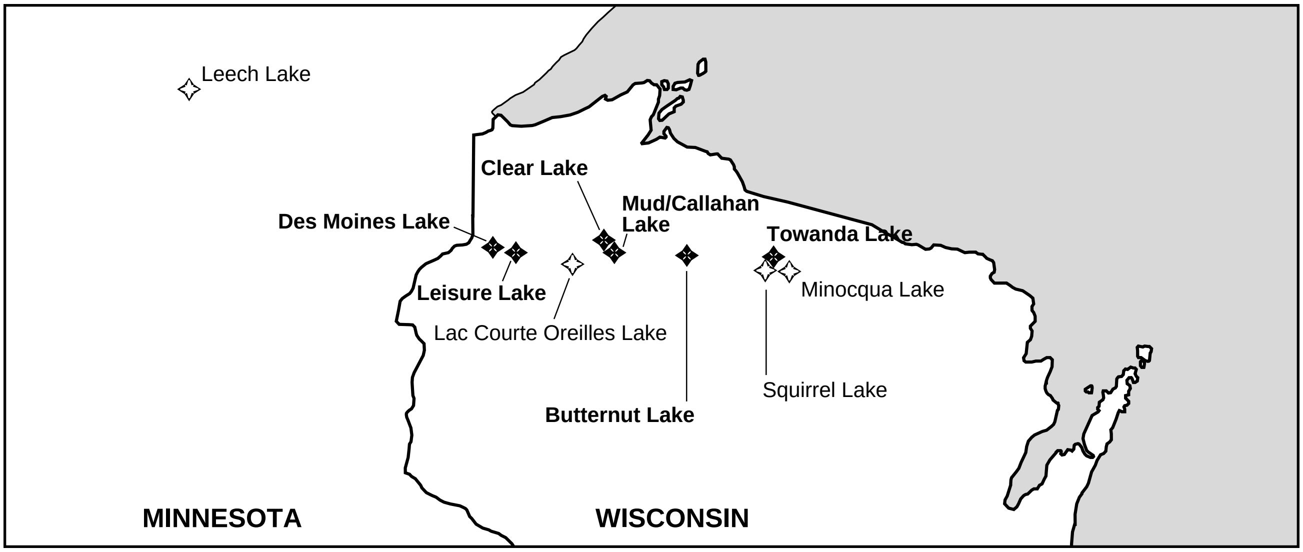

Figure 1. *Location of muskellunge populations and study lakes. Open symbols indicate parent populations and closed symbols represent study lakes. Mud/Callahan Lake was both a parent population and study lake.*

Methods

Five muskellunge populations were selected to compare relative survival and growth (Figure 1). Populations included brood lakes commonly used for propagation, and one stunted population. Lac Courte Oreilles (Sawyer County), Minocqua and Squirrel lakes, (Vilas County) are brood lakes for egg collection for the Wisconsin muskellunge program. Leech Lake (Minnesota) muskellunge are used for the Minnesota propagation program. Mud/Callahan Lake (Sawyer County) muskellunge have historically exhibited slow growth and poor size structure (Hanson 1993).

Six lakes located in northern Wisconsin received a single paired stocking of fingerling muskellunge from two of the above mentioned populations, while one lake received a single stocking from four different populations (Figure 1). Primary comparisons were between Lac Courte Oreilles (LCO) and Mud/Callahan (M/C) populations, however other stockings included Minocqua (MQ), Squirrel (SQ), and Leech Lake (LL) populations (Table 1). Study lakes stocked with fingerlings included Clear Lake (77 acres, Sawyer County), Leisure Lake (75 acres, Washburn County), Des Moines Lake (229 acres, Burnett County), Mud/Callahan lakes (586 acres, Sawyer County), Towanda Lake (146 acres, Vilas County), and Butternut Lake (1,006 acres, Price County).

Muskellunge fingerlings were pond reared on a minnow diet from eggs collected from wild populations. In 1981, M/C and LCO fingerlings for stocking Clear Lake were reared at the Spooner Hatchery. However, fingerlings from LCO were considerably larger than those from M/C (LCO = 11.0 inches; M/C = 8.6 inches). In 1982, LCO fingerling for stocking Mud/Callahan, Leisure, and Des Moines lakes were reared in an outlying pond (Sand Lake pond) near Spooner and M/C fingerlings were reared at the Spooner Hatchery; mean size at stocking was similar (LCO = 9.7 inches; M/C = 9.7 inches). MQ and SQ muskellunge were reared at the Woodruff Hatchery. LL muskellunge were reared at Hinckley, Minnesota. All stocked muskellunge were given a fin clip prior to release for identification (Table 1).

Muskellunge sampling was conducted using a boat-mounted AC electroshocker and fyke nets. Electroshocking was used during fall to sample immature fish (generally < 5 years old), while spring fyke netting during the spawning period was the primary gear for sampling mature muskellunge (age 5+). Sampling continued on study lakes for 7 years following stocking unless capture of stocked fish was insufficient to warrant further sampling. Upon capture, mature muskellunge were often given pre-opercle tags (Johnson 1971) to facilitate identification as fin clips regenerated (McNeil and Crossman 1979). This marking also allowed for determining other population parameters where sample size was adequate. Abundance of adult muskellunge ($\geq$22 inches) in Mud/Callahan in 1987 was estimated using the Bailey method (Ricker 1975). Muskellunge were captured in 2 consecutive years using fyke nets during the spring spawning

Table 1. *Summary of muskellunge stockings in six Wisconsin lakes.*

Lake	County	Surface Acres	Year	Fin Clip[a]	Parent Population[b]	Number Stocked	Mean Length (inches)	Mean Weight (g)
Clear	Sawyer	77	1981	LV	M/C	89	8.6	–
				LP	M/C	88	8.6	–
				RV	LCO	89	11.0	–
				RP	LCO	88	11.0	–
Leisure	Washburn	75	1982	LV	M/C	100	9.7	87
				LP	M/C	100	9.7	87
				RV	LCO	100	9.7	77
				RP	LCO	100	9.7	77
Mud/Callahan	Sawyer	586	1982	LV	M/C	500	9.7	87
				LP	M/C	500	9.7	87
				RV	LCO	500	9.7	77
				RP	LCO	500	9.7	77
Des Moines	Burnett	229	1982	LV	M/C	229	9.7	87
				LP	SQ	229	9.8	74
				RV	LCO	229	9.7	77
				RP	MQ	229	10.0	81
Towanda	Vilas	146	1984	LV	LCO	150	11.4	–
				LP	LCO	150	11.4	–
				RV	LL	150	11.7	118
				RP	LL	150	11.7	118
Butternut	Price	1,006	1984	LV	LCO	499	11.6	125
				LP	LCO	494	11.6	125
				RV	MQ	500	9.7	71
				RP	MQ	500	9.7	71

[a] Fin clip - LV = Left pelvic; LP = Left pectoral; RV = Right pelvic; RP = right pectoral.
[b] Parent population - M/C = Mud/Callahan; LCO = Lac Courte Oreilles; SQ = Squirrel; MQ = Minocqua; LL = Leech.

period. Muskellunge captured in the first year made up the marking run, and those captured in the second year, the recapture run. Numbers of fish included in the recapture run were adjusted for recruitment over a 1-year period using sex-specific growth rates.

Analysis of survival and growth for stocked muskellunge was difficult. While sampling occurred over a considerably long period (7 years), sample numbers were often low and stocked fish were not individually marked. Hence individual fish may have been captured multiple times, but nothing was known about the number of captures or their timing for any fish. Burnham et al. (1987) refer to this as "the unknown capture history" design, and generally recommend against its use; observations may not be independent and it is not possible to separate survival effects from capture probability. As an alternative we used chi-square tests to compare the proportion of stocked fish that were recaptured at a specific time. We constructed 2×2 contingency tables, comparing groups of fish and whether or not fish were captured. This test allows a comparison at each capture time. Survival of stocked fish was compared at two periods: shortly after stocking (40-55 d) and at maturity (ages 5, 6, and 7). Short-term survival was also compared by estimating abundance of stocked fish with mark-recapture population estimates (Everhart and Youngs 1981).

Direct comparisons of mean length at age were made using analysis of variance when sufficient numbers ($n \geq 5$) of fish were sampled. However, because of the small numbers of fish sampled in many lakes, we pooled data for lakes other than Mud/Callahan for comparative purposes. Several indices were also used to compare growth (length and weight) of stocked fish at ages 5, 6, and 7. We used relative weight (W_r) as an indicator of condition of muskellunge (Neumann and Willis 1994). We also used a growth standard for length developed by Casselman and Crossman (1986). The growth index compares growth rates in a given lake to an established length standard. Growth indices are reported as a percent compared to the growth standard.

The large number of LCO and M/C muskellunge sampled in Mud/Callahan Lake allowed for additional analysis. Growth histories were constructed for male and female muskellunge stocked into Mud/Callahan Lake using back-calculated length at age from scale interpretations and empirical growth

Table 2. *Population and short-term survival estimates from four muskellunge populations in study lakes.*

	Lake and Year Stocked					
Parent Population Parameter	Clear 1981	Leisure 1982	Mud/ Callahan 1982	Des Moines 1982	Towanda 1984	Butternut 1984
Mud/Callahan						
P.E.[a]	70	95	157	50	–	–
95% CI	46-151	73-176	106-301	21-136	–	–
DAL	40	51	55	50	–	–
OBS	39.1	47.5	15.7	21.8	–	–
Lac Courte Oreilles						
P.E.	80	52	119	30	179	601
95% CI	53-163	42-66	78-255	26-37	112-246	491-711
DAL	40	51	55	50	41	41
OBS	44.7	26.0	11.9	13.1	59.5	60.5
Minocqua						
P.E.	–	–	–	31	–	445
95% CI	–	–	–	20-78	–	324-566
DAL	–	–	–	50	–	42
OBS	–	–	–	13.6	–	44.5
Squirrel						
P.E.	–	–	–	19	–	–
95% CI	–	–	–	10-209	–	–
DAL	–	–	–	50	–	–
OBS	–	–	–	8.3	–	–
Leech						
P.E.	–	–	–	–	158	–
95% CI	–	–	–	–	116-200	–
DAL	–	–	–	–	41	–
OBS	–	–	–	–	52.7	–

[a] P.E. = Population estimate; 95% CI = 95% confidence interval for population estimate; DAL = Days at large from stocking to population estimate; OBS = Observed survival.

data from mature fish. Growth information was fitted to a von Bertalanffy equation (Prager et al. 1989) to predict the maximum asymptotic length of M/C and LCO muskellunge in Mud/Callahan. Asymptotic length predictions were compared with actual length frequency distributions of resident muskellunge in Mud/Callahan. No comparisons were made for Clear, Des Moines, Leisure, Towanda, or Butternut lakes because of small sample sizes.

Results and Discussion

Insufficient replication of stockings of different muskellunge populations in study lakes, and low numbers of adult muskellunge recaptured made data analysis and conclusions from this study limited and difficult. Primary comparisons were made between LCO and M/C muskellunge, where fingerlings from these two populations were stocked into four lakes together. Muskellunge fingerlings from the three other populations (MQ, SQ, and LL) were only stocked into 1-2 lakes.

Short-term Survival

Observed survival of stocked muskellunge 40-55 d following stocking averaged 32.8% (n = 14) and ranged from 8.3 to 60.5% (Table 2). Lowest survival was for SQ muskellunge stocked in Des Moines Lake while highest was LCO muskellunge in Butternut lake. These survival rates are within the range reported for fall fingerling in Wisconsin. Hanson et al. (1986) found a mean short-term survival rate for stocked fall fingerlings of 38.7% for 68 stockings, and Margenau (1992) found a mean survival of 37.7% for 14 stockings.

In general, LCO fish had lower survival rates than M/C fish when they were stocked into the same lake (Table 2). Mean estimated survival in Leisure, Mud/Callahan, and Des Moines lakes for M/C muskellunge was 28.3% compared to 17.0% for LCO muskellunge. However, when the number of LCO and M/C fish captured were compared within lakes, significant differences occurred only in Des Moines Lake (χ^2 = 5.8; P = 0.02, df = 1). Clear Lake was excluded from this analysis because of the size difference at stocking (LCO = 11.0 inches; M/C = 8.6 inches). The difference in survival between LCO (44.7%) and M/C (39.1) may be at least partly due to length at stocking. Hanson et al. (1986) and Margenau (1992) found size-dependent survival of fingerling muskellunge the first fall after stocking.

Survival comparisons in other lakes were somewhat equivocal. Capture numbers and survival estimates of LCO and MQ muskellunge in Butternut Lake suggest LCO fish had higher survival than MQ (χ^2 = 32.7; P < 0.001, df = 1). Estimated survival of LCO muskellunge was 60.5% compared to 44.5% for MQ muskellunge. No differences were seen in Towanda Lake where LCO and LL muskellunge were stocked (χ^2 = 1.0; P = 0.31, df = 1). Survival of LCO muskellunge was 59.5% compared to 52.7% for LL muskellunge. Survival differences did occur in Des Moines Lake among the four stocked groups (χ^2 = 10.3; P = 0.02, df = 3) with M/C survival being the highest. Estimated survival of M/C fish was 21.8% compared to 13.1% for LCO, 13.6% for MQ, and 8.3% for SQ.

Survival to Maturity

Survival to ages 5 through 7 was difficult to assess because of low numbers of fish captured in most study lakes. Relative survival comparisons, based on captured individuals, were possible only for Mud/Callahan Lake and Clear Lake. In Mud/Callahan Lake, M/C muskellunge were more abundant than LCO muskellunge at age 5, 6, and 7 (P < 0.01). In Clear Lake there was no significant difference between M/C and LCO muskellunge at either ages 5 or 6 (P = 0.40). However, results from the Clear Lake may be a reflection of small sample sizes (age 5, n = 13; age 6, n = 13).

Growth

In general, LCO muskellunge grew faster than M/C muskellunge where they occurred together, however the difference varied between lakes (Figure 2). Comparisons between MQ, LL, and SQ muskellunge with LCO muskellunge were not possible because of small sample sizes. Statistical comparisons of mean length at age were only possible in Mud/Callahan and Clear lakes. Mean length of LCO muskellunge was significantly greater than M/C muskellunge in Mud/Callahan Lake at ages 5,6, and 7 (P < 0.05). LCO muskellunge were also longer than M/C muskellunge in Clear Lake (P < 0.05), however the length difference in Clear Lake may be partly due to size at stocking. Margenau (1992) observed size differences at stocking to continue at least until age 18 months. It is unknown whether or not these size effects remain until later ages.

The environment that fish were stocked into seemed to have an effect on their growth. M/C muskellunge reached greater lengths at age in waters other than Mud/Callahan (Table 3). Mean length of pooled data for lakes stocked with M/C

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Short-term survival of stocked muskellunge was higher for Mud/Callahan fingerlings compared to Lac Courte Oreilles fingerlings, but all survival rates were within the range of survival previously reported for Wisconsin lakes.

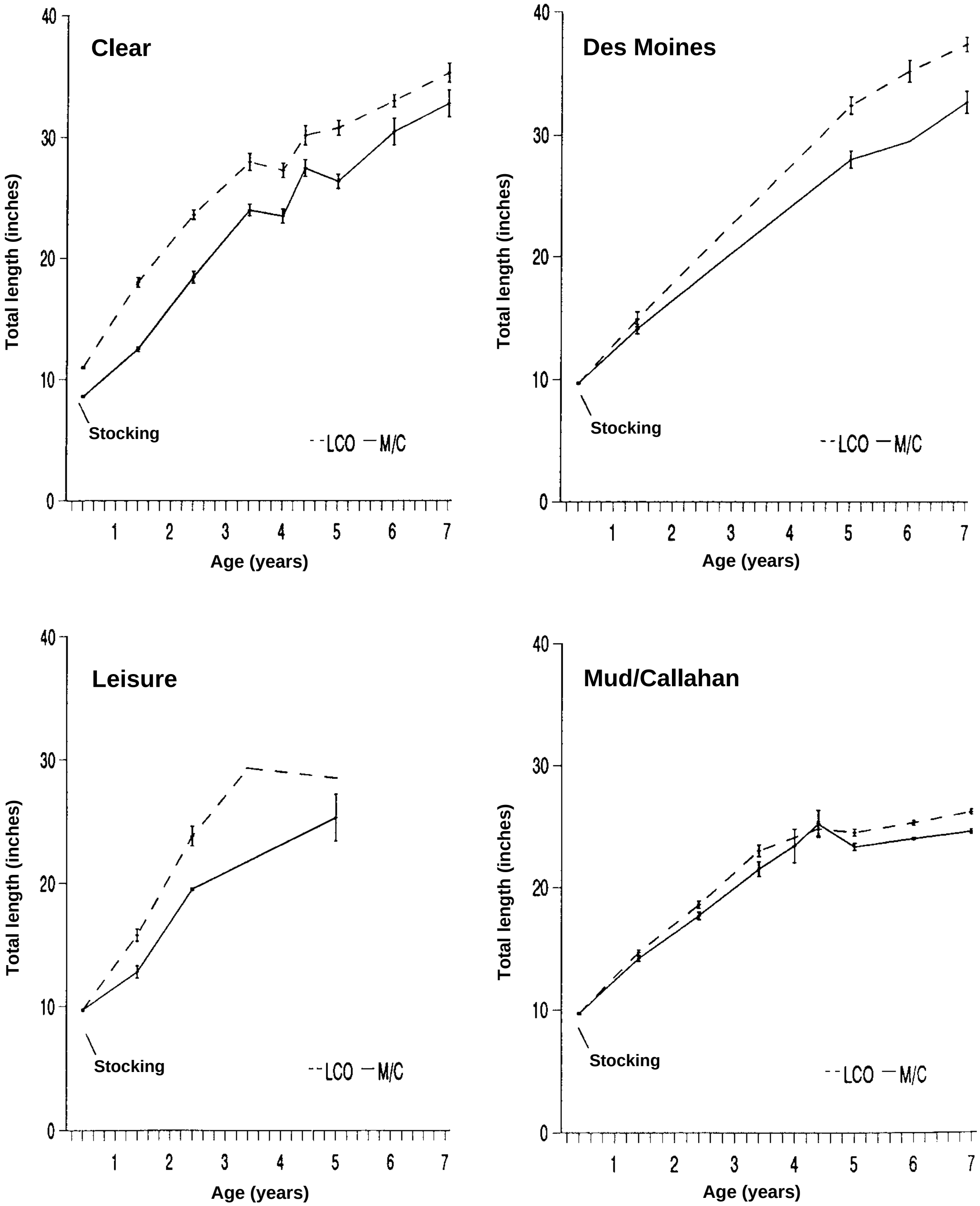

Figure 2. *Mean length at age for muskellunge in study lakes. Vertical bars represent 95% confidence interval of the mean.*

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Environmental conditions affected muskellunge growth. This LCO female muskellunge stocked into Mud/Callahan Lake measured less than 26 inches at age 7.

fish was significantly greater than similar aged fish stocked into Mud/Callahan ($P < 0.001$). By age 7 mean length of M/C muskellunge was 24.7 inches for Mud/Callahan Lake while mean length in other study lakes was 32.7 inches (Table 3). Similarly, LCO muskellunge stocked into Mud/Callahan Lake experienced lower mean lengths compared to pooled length data for LCO muskellunge from other stocked lakes ($P < 0.001$). Mean length of LCO muskellunge at age 7 in Mud/Callahan Lake was 26.2 inches compared to 35.8 inches for pooled data for other study lakes (Table 3).

Growth index calculations reflected the slower growth rates by both LCO and M/C fish in Mud/Callahan Lake. The growth index for M/C and LCO muskellunge in Mud/Callahan was 64.6% and 68.8%, respectively. Both of these values are below the lowest growth index reported by Casselman and Crossman (1986) of 78% for Nogies Creek, Ontario. Crossman (1956) suggested that lack of sufficient forage for muskellunge greater than age III contributed to the small size structure (mean size = 21 inches) and high mortality observed in the Nogies Creek population. In contrast, the growth index of M/C and LCO muskellunge in other study lakes was higher. The growth index of M/C and LCO muskellunge was 80.7% and 89%, respectively. These values fall near the growth index of 84% calculated for several Wisconsin Lakes (Bone, Lac Courte Oreilles, and Big Spider) taken from (Johnson 1971) and reported by Casselman and Crossman (1986). Hence, it seems that in other study waters M/C muskellunge growth improved but was still less than that of LCO fish.

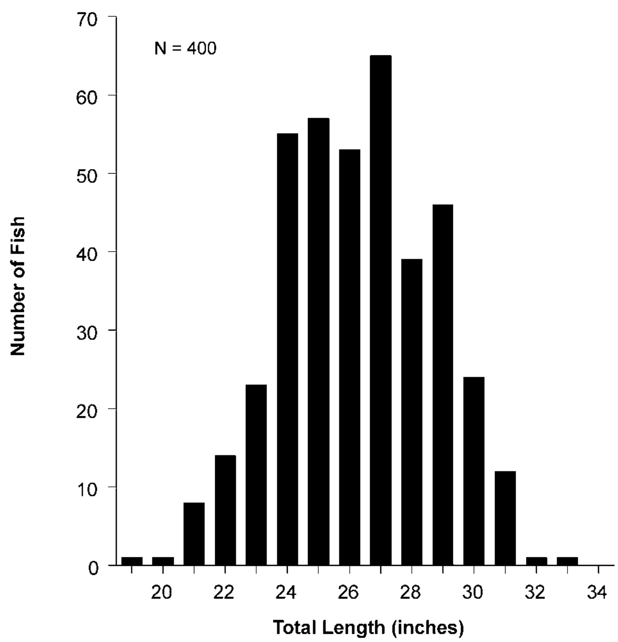

Figure 3. *Length frequency distribution of resident muskellunge in Mud/Callahan Lake, 1988.*

Relative weight (W_r) of M/C muskellunge in Mud/Callahan Lake was higher than for LCO muskellunge at ages 5-7 though the difference was not significant ($P = 0.07$). Mean W_r for M/C muskellunge was 83 ($n = 291$) compared to 81 ($n = 160$) for LCO muskellunge. These values fall within the range of 73-126 presented by Neumann and Willis (1994) for muskellunge from 20-30 inches, but are below the calculated mean of 94 ($n = 42$).

Asymptotic length predictions for both LCO and M/C muskellunge in Mud/Callahan were less than 30 inches for both male and female fish. The von Bertalanffy predictions for female LCO muskellunge were 29.1 inches compared to 27.2 inches for M/C females. Male muskellunge asymptotic lengths were similar (LCO = 28.5 inches, M/C = 28.6 inches). Using the upper 95% confidence limit of the von Bertalanffy prediction for asymptotic length extends the possible maximum length to 31.0 in for LCO muskellunge and 32.6 inches for M/C muskellunge.

The von Bertalanffy predictions for maximum potential length seem to fit the length frequency distribution of Mud/Callahan resident muskellunge (stocked fish not included) quite well (Figure 3). In 1988, few resident muskellunge > 30 inches were sampled and no fish > 33 inches were sampled . Additional support for the limited size potential and poor growth of muskellunge in Mud/Callahan Lake was provided by recovery of muskellunge previously tagged by Hanson (1993) and recaptured during this

Table 3. *Mean length of M/C and LCO muskellunge in Mud/Callahan and other study lakes. Sample size in parentheses.*

		Age		
Parent Population	**Lake Stocked**	**5**	**6**	**7**
Lac Courte Oreilles				
	Mud/Callahan	24.5 (32)	25.4 (83)	26.2 (45)
	Other lakes[a]	29.9 (23)	32.8 (25)	35.8 (8)
Mud/Callahan				
	Mud/Callahan	23.3 (56)	24.0 (149)	24.7 (87)
	Other lakes[b]	26.4 (10)	30.3 (6)	32.7 (5)

[a] Includes Clear, Butternut, Leisure, Des Moines, and Towanda lakes.
[b] Includes Clear, Leisure, and Des Moines lakes.

Table 4. *Growth and capture histories of muskellunge from Mud/Callahan Lake. (R) represents regenerated scales.*

Tag Number	1979 Length	1979 Age[a]	1979 Sex	Recapture Data Year	Recapture Data Years at Large	Recapture Data Length	Recapture Data Calculated Growth/ Year (inches)	Recapture Data Age[a]	Recapture Data Partly Known-age[b]	Recapture Data Deviation[c]
5202	25.5	6	M	1987	8	27.4	0.2	8	14	-6
5221	23.8	5	F	1987	8	25.2	0.2	9	13	-4
5259	22.8	4	M	1987	8	26.5	0.5	10	12	-2
5448	24.7	5	F	1987	8	27.7	0.4	9	13	-4
5469	25.1	6	F	1987	8	27.6	0.3	9	14	-5
5611	27.4	6	F	1987	8	27.6	<0.1	9	14	-5
5614	24.2	6	F	1987	8	27.6	0.4	R	14	—
5661	26.0	6	F	1987	8	27.3	0.2	9	14	-5
5302	26.0	8	M	1988	9	28.2	0.2	11	17	-6
5312	26.2	8	M	1988	9	29.2	0.3	11	17	-6
5330	23.5	5	M	1988	9	27.0	0.4	9	14	-5
5355	22.3	6	M	1988	9	24.3	0.2	R	15	—
5543	23.4	6	M	1988	9	30.0	0.7	9	15	-6
Mean							0.3			-4.9

[a] Assessed from scale impression.
[b] Assessed age in 1979 plus known years at large.
[c] Partly known-age minus assessed age at recapture.

study following 8-9 years at large. Of 13 muskellunge tagged in 1979 and recaptured in either 1987 or 1988, the calculated growth rate per year was 0.3 inches (Table 4). Recovery of these fish also demonstrated serious problems with age determination using scales with muskellunge in extremely slow growing populations. Using the age interpretation from 1979 added to years at large (partly known-age) indicated some of these muskellunge to be 17 years old and still < 30 inches. However, scale interpretations from the recapture period (1987 or 1988) aged these fish no older than 11 years. The mean deviation between the partly-known age and scale interpretation at recapture was nearly 5 years less than the partly-known age (Table 4).

Abundance of resident muskellunge in Mud/Callahan Lake ≥ 22 inches in 1987 was estimated at 1,464 fish (95% C.I. = 1,186-1,742). Abundance of stocked muskellunge (LCO and M/C) was estimated at 374 fish (95% C.I. = 266-482). Together an estimated 1,838 muskellunge ≥ 22 inches or a density of 3.1/acre were present in 1987. Abundance of similar size muskellunge in 1979 was estimated at 1,210 (95% C.I. = 1,053-1,367) or a density of 2.1/acre (Hanson, DNR, unpublished data). Hence, while the estimates of 1979 and 1987 resident muskellunge were reasonably similar, the addition of the stocked LCO and M/C muskellunge into a population already experiencing poor growth increased the population 52% and may have magnified the growth problem.

Summary

Paired stockings of muskellunge fingerlings in six Wisconsin lakes were conducted to evaluate differential survival and growth of selected populations. Interpretation of results was difficult because of insufficient replication of stockings in lakes, and low numbers of stocked fish sampled at maturity. Sample size problems were also encountered during a similar study in Minnesota (Younk and Strand 1992).

Short-term (<60 d) survival of stocked fish was in the range reported for fingerlings in Wisconsin. Survival of M/C fingerlings was generally higher than LCO fingerlings. At maturity, M/C muskellunge were also more abundant than LCO muskellunge in Mud/Callahan Lake.

Growth comparisons suggested LCO muskellunge reach larger sizes at age than M/C muskellunge. However, environmental factors seemed to also contribute to muskellunge length. In Mud/Callahan Lake, growth of both M/C and LCO muskellunge was inhibited, while in other study lakes growth improved but was still slower for M/C muskellunge.

Muskellunge in Mud/Callahan Lake were characterized by a dense slow-growing population. Most adult fish were <30 inches and data from partly known-age fish suggests some were as old as 17 years. Growth problems in Mud/Callahan Lake appear to be largely environmental but genetic factors also contribute to the small size of fish.

Management Implications

Koppelman and Philipp (1986) stress the need for genetic conservation in management of muskellunge. While conclusions from this study are limited in scope due to sample sizes in most lakes, the case history information from Mud/Callahan Lake stands alone in demonstrating the importance of stock management. Muskellunge in Mud/Callahan Lake were size limited possibly by food resources. As a result fish did not reach large sizes. When M/C progeny were stocked into other waters their growth rates improved, but length at age was still less than LCO muskellunge. Hence, growth (i.e., length at age for M/C and LCO muskellunge) seemed to be influenced by both environmental and genetic factors.

An alternative explanation for the observed growth/size structure in Mud/Callahan and Lac Courte Oreilles would implicate angler harvest. Long-term harvest trends by anglers targeting larger fish may cause a natural adaptive shift toward earlier maturing (and slower growing) fish in Mud/Callahan Lake. A similar selective process would not be present in Lac Courte Oreilles because selection (for egg collection) is artificial (by hatchery workers) and often toward larger fish.

While growth is slow, the Mud/Callahan muskellunge population was self-sustaining, suggesting this population has adapted to the specific conditions, i.e. low levels of forage or harvest conditions in Mud/Callahan Lake.

Old age, slow growth populations such as the one present in Mud/Callahan require special consideration for management. Good growth and subsequent large size are desired traits for muskellunge management. Hence, even though the Mud/Callahan population is well adapted to environmental conditions in Mud/Callahan Lake, the fishery is not desirable to anglers. Management options for slow growth populations might consider special size limits that would encourage harvest of smaller individuals while offering protection to larger fish in the population.

The higher survival of M/C muskellunge compared to LCO muskellunge is of interest, and to suggest a reason is speculative. Possibly, M/C fish are somehow behaviorly different from LCO fish, making them less vulnerable to predation. As mentioned above, the Mud/Callahan population is self-sustaining through natural reproduction, while the Lac Courte Oreilles population is sustained through stocking, and as such, artificial selection acts on the early-life history stages. Differences such as these should be looked at more in depth in future research studies.

The low number of adult recaptures in most study waters probably reflects low survival at early ages. A loss of nearly 70% of the stocked fish within the first several months following release leaves few remaining fish to survive to maturity. These encounters are inherently problematic when dealing with a species that requires 5-7 years to reach maturity. In future studies that require muskellunge to reach maturity, several options are available to increase chances of capturing adequate numbers of fish. First, yearling muskellunge have been shown to have higher survival and be more cost-effective than typical fall fingerling stocking (Margenau 1992). Using yearling fish for stocking evaluations such as this one would increase the chances of more fish reaching the adult population. Second, standard fingerling stocking rates could be increased. While this option may be costly, the number of fish surviving short-term mortality may be adequate to allow assessment at adult ages.

Age assessment of muskellunge using scale samples has been suspect, especially for fish > 10 years of age (Casselman 1983). This situation becomes more troublesome when dealing with slow growth populations. Recovery of tagged muskellunge in Mud/Callahan Lake after 8-9 years at large indicated fish could be nearly 20 years old and still < 30 inches. Interpretation of scale samples from these fish was nearly 5 years less than the partly known age.

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Slow-growth muskellunge populations may require special management attention to provide fisheries acceptable to sport anglers.

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